CLAIMS

I Claim:

1   1.   A method of producing a wideband signal from a narrowband signal, the method

2   comprising:

3   computing M_{nb} area coefficients from the narrowband signal;

4   interpolating the M_{nb} area coefficients into M_{wb} area coefficients;

5   generating a highband signal using the M_{wb} area coefficients; and

6   combining the highband signal with the narrowband signal interpolated to the

7   highband sampling rate to form the wideband signal.

1   2.   The method of claim 1, wherein computing M_{nb} area coefficients further

2   comprises computing M_{nb} area coefficient using the following equation:

3    $$A_i = \frac{1 + r_i}{1 - r_i} A_{i+1}; \quad i = M_{nb}, M_{nb} - 1, ..., 1,$$

4   where A_1 corresponds to a cross-section at the lips, $A_{M_{nb}+1}$ correspond to cross-

5   sections of the vocal tract at the glottis opening and r_i are reflection coefficients.

1   3.   The method of claim 1, wherein interpolating the M_{nb} area coefficients into

2   M_{wb} area coefficients further comprises interpolating using a linear first order

3   polynomial interpolation scheme.

1   4.   The method of claim 1, wherein interpolating the M_{nb} area coefficients further

2   comprises interpolating using a cubic spline interpolation scheme.

1   5.   The method of claim 1, wherein interpolating the M_{nb} area coefficients further

2   comprises interpolating using a fractal interpolation scheme.

1   6.   The method of claim 1, further comprising:

2   insuring that the interpolated M_{wb} area coefficients are positive; and

3   setting $A_{M_{wb}+1}^{wb}$ to a finite positive fixed value.

1   7.   The method of claim 1, wherein interpolating the M_{nb} area coefficients further

2   comprises interpolating by a factor of 2, with a ¼ sampling interval shift.

1   8.   A method of bandwidth extension of a narrowband signal, the method

2   comprising:

3   computing M_{nb} log-area coefficients from the narrowband signal;

4   interpolating the M_{nb} log-area coefficients into M_{wb} log-area coefficients;

5   generating a highband signal using the interpolated M_{wb} log-area coefficients;

6   and

7   combining the highband signal with the narrowband signal interpolated to the

8   highband sampling rate to generate a wideband signal.

1   9.   The method of claim 8, wherein computing M_{nb} log-area coefficients further

2   comprises computing M_{nb} area coefficients using the equation below and computing

3   their logarithmic values:

4
$$A_i = \frac{1 + r_i}{1 - r_i} A_{i+1}; \quad i = M_{nb}, M_{nb} - 1, \ldots, 1,$$

5   where A_1 corresponds to a cross-section at the lips, $A_{M_{nb}+1}$ correspond to cross-sections

6   of the vocal tract at the glottis opening and r_i are reflection coefficients.

1   10.   The method of claim 8, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating using a linear first order polynomial interpolation

3   scheme.

1   11.   The method of claim 8, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating using a cubic spline interpolation scheme.

1   12.   The method of claim 8, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating using a fractal interpolation scheme.

1   13.   The method of claim 8, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating by a factor of 2, with a ¼ sample shift.

1   14.   A method of extending the bandwidth of a narrowband signal, a preprocessing of

2   the narrowband signal producing narrowband partial correlation coefficients (parcors),

3   the method comprising:

4   (1)   computing M_{nb} area coefficients from the narrowband parcors;

5   (2)   computing M_{nb} log-area coefficients from the M_{nb} area coefficients;

6   (3)   obtaining M_{wb} log-area coefficients from the M_{nb} log-area coefficients;

7   (4)   computing M_{wb} area coefficients from the M_{wb} log-area coefficients;

8   (5)   computing wideband parcors from the M_{wb} area coefficients;

9   (6)   generating a highband signal using the wideband parcors; and

10   (7)   combining the highband signal with the narrowband signal interpolated

11 to the highband sampling rate.

1 15.   The method of extending the bandwidth of a narrowband signal of claim 14,

2 wherein obtaining M_{wb} log-area coefficients further comprises obtaining M_{nb} times

3 two log-area coefficients using interpolation.

1 16.   A method of producing a wideband signal from a narrowband signal, the method

2 comprising:

3   (1)   computing narrowband linear predictive coefficients (LPCs) from the

4 narrowband signal;

5   (2)   computing narrowband parcors r_i associated with the narrowband LPCs;

6   (3)   computing M_{nb} area coefficients A_i^{nb}, $i = 1, 2,...,M_{nb}$ using the

7 following: $A_i = \dfrac{1+r_i}{1-r_i}A_{i+1};\quad i = M_{nb}, M_{nb} - 1,...,1,$

8 where A_1 corresponds to a cross-section at lips, $A_{M_{nb}+1}$ and corresponds to a

9 cross-section of a vocal tract at a glottis opening;

10   (4)   extracting M_{wb} area coefficients from the M_{nb} area coefficients using

11 interpolation;

12   (5)   computing wideband parcors using the M_{wb} area coefficients according

13 to the following:

14 $$r_i^{wb} = \frac{A_i^{wb} - A_{i+1}^{wb}}{A_i^{wb} + A_{i+1}^{wb}}, \quad i = 1, 2, ..., M_{wb};$$

15   (6)   computing wideband LPCs a_i^{wb}, $i = 1, 2, ..., M_{wb}$, from the wideband

16 parcors; and

17   (7)   synthesizing a wideband signal y_{wb} using the wideband LPCs and an

18 excitation signal.

1   17.   The method of producing a wideband signal from a narrowband signal of claim

2 16, the method further comprising:

3   (8)   highpass filtering the wideband signal y_{wb} to generate a highband signal;

4 and

5   (9)   combining the highband signal with the narrowband signal interpolated

6 to the wideband sampling rate to produce a wideband signal $\hat{s}_{wb}$.

1   18.   The method of producing a wideband signal from a narrowband signal of claim

2 16, wherein extracting M_{wb} area coefficients from the M_{nb} area coefficients using

3 shifted-interpolation further comprises interpolating by a factor of 4 followed by a single

4 sample shift and decimating by a factor of 2.

1   19.   The method of producing a wideband signal from a narrowband signal of claim

2 16, the method further comprising:

3   (8)   generating the excitation signal from a narrowband prediction residual

4 signal using fullwave rectification.

1   20.   The method of producing a wideband signal from a narrowband signal of claim

2   16, wherein M_{wb} equals two times M_{nb}.

1   21.   The method of producing a wideband signal from a narrowband signal of claim

2   16, wherein extracting M_{wb} area coefficients from the M_{nb} area coefficients using

3   shifted-interpolation further comprises interpolating by a factor of 2 with a ¼ sample

4   shift.

1   22.   The method of producing a wideband signal from a narrowband signal of claim

2   16, wherein extracting M_{wb} area coefficients from the M_{nb} area coefficients using

3   shifted-interpolation further comprises using a first order linear shifted-interpolation.

1   23.   The method of producing a wideband signal from a narrowband signal of claim

2   16, wherein extracting M_{wb} area coefficients from the M_{nb} area coefficients using

3   shifted-interpolation further comprises using cubic-spline interpolation.

1   24.   The method of producing a wideband signal from a narrowband signal of claim

2   16, wherein extracting M_{wb} area coefficients from the M_{nb} area coefficients using

3   shifted-interpolation further comprises using fractal interpolation.

1   25.   A method of extending the bandwidth of a narrowband signal, the method

2   comprising:

3   (1)   computing narrowband linear predictive coefficients (LPCs) from the

4   narrowband signal;

5   (2)   computing narrowband parcors associated with the narrowband LPCs;

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6   (3)   computing M_{nb} area coefficients using the narrowband parcors;

7   (4)   extracting M_{wb} area coefficients from the M_{nb} area coefficients using

8 shifted-interpolation;

9   (5)   converting the M_{wb} area coefficients into wideband LPCs; and

10   (6)   synthesizing a wideband signal y_{wb} using the wideband LPCs and an

11 excitation signal.

1   26.   The method of extending the bandwidth of a narrowband signal of claim 25, the

2 method further comprising:

3   (7)   highpass filtering the wideband signal y_{wb} to produce a highband signal;

4 and

5   (8)   combining the highband signal with the narrowband signal interpolated

6 to the wideband sampling rate to produce a wideband signal $\hat{s}_{wb}$.

1   27.   The method of extending the bandwidth of a narrowband signal of claim 25,

2 wherein the step of converting the M_{wb} area coefficients into wideband LPCs further

3 comprising computing wideband parcors from the M_{wb} area coefficients and using

4 step-down back-recursion to compute the wideband LPCs.

1   28.   The method of extending the bandwidth of a narrowband signal of claim 25, the

2 method further comprising computing the excitation signal from a narrowband

3 prediction residual signal.

1   29.   The method of extending the bandwidth of a narrowband signal of claim 25,

2 wherein the higher band of the excitation signal is highpass filtered white noise.

1 30.   A method of extending the bandwidth of a narrowband signal, the method

2 comprising:

3   (1)   computing narrowband linear predictive coefficients (LPCs) from the

4 narrowband signal;

5   (2)   computing M_{nb} area coefficients using the narrowband LPCs;

6   (3)   extracting M_{wb} area coefficients from the M_{nb} area coefficients using

7 interpolation;

8   (4)   converting the M_{wb} area coefficients into wideband LPCs; and

9   (5)   synthesizing a wideband signal y_{wb} using the wideband LPCs and

10 highpass filtered white noise in the higher band of an excitation signal and a linear

11 prediction residual signal in the lower band of the excitation signal.

1 31.   The method of extending the bandwidth of a narrowband signal of claim 30,

2 wherein computing the excitation signal from a narrowband prediction residual signal

3 further comprises inverse filtering the narrowband signal.

1 32.   A method of producing a wideband signal from a narrowband signal, the method

2 comprising:

3   (1)   producing a wideband excitation signal from the narrowband signal;

4   (2)   computing partial correlation coefficients r_i (parcors) from the

5 narrowband signal;

6   (3)   computing M_{nb} area coefficients according to the following equation:

7
$$A_i = \frac{1 + r_i}{1 - r_i} A_{i+1}; \quad i = M_{nb}, M_{nb} - 1, \ldots, 1,$$

8   where A_1 corresponds to the cross-section at lips and $A_{M_{nb}+1}$

9   corresponds to the cross-section at a glottis opening;

10   (4)   extracting M_{wb} area coefficients from the M_{nb} area coefficients using

11   interpolation;

12   (5)   computing wideband parcors r_i^{wb} from the interpolated M_{wb} area

13   coefficients according to the following:

14
$$r_i^{wb} = \frac{A_i^{wb} - A_{i+1}^{wb}}{A_i^{wb} + A_{i+1}^{wb}}, \quad i = 1, 2, ..., M_{wb};$$

15   (6)   computing wideband linear predictive coefficients (LPCs) a_i^{wb} from the

16   wideband parcors r_i^{wb};

17   (7)   synthesizing a wideband signal y_{wb} from the wideband LPCs a_i^{wb} and

18   the wideband excitation signal;

19   (8)   highpass filtering the wideband signal y_{wb} to produce a highband signal;

20   and

21   (9)   generating a wideband signal $\hat{s}_{wb}$ by summing the highband signal and

22   the narrowband signal interpolated to the wideband sampling rate.

1   33.   The method of producing a wideband signal from a narrowband signal of claim

2   32, wherein producing the wideband excitation signal from the narrowband signal further

3   comprises:

4   performing linear prediction on the narrowband signal to find a_i^{wb} LP

5   coefficients;

6   interpolating the narrowband signal to produce an upsampled narrowband signal;

7   producing a narrowband residual signal $\tilde{r}_{nb}$ by inverse filtering the upsampled

8   interpolated narrowband signal using a transfer function associated with the a_i^{wb} LP

9   coefficients; and

10   generating the wideband excitation signal from the narrowband residual signal

11    $\tilde{r}_{nb}$.

1   34.   A method of producing a wideband signal from a narrowband signal, the method

2   receiving data associated with a narrowband signal, the method comprising:

3   (1)   computing M_{nb} area coefficients using the narrowband data;

4   (2)   extracting M_{wb} area coefficients from the M_{nb} area coefficients using

5   interpolation; and

6   (3)   synthesizing a wideband signal y_{wb} using wideband coefficients

7   processed from data associated with the M_{nb} area coefficients and an excitation signal.

1   35.   The method of producing a wideband signal from a narrowband signal of claim

2   34, the method further comprising:

3   (4)   highpass filtering the wideband signal y_{wb} to form a highband signal;

4   and

5   (5)   generating a wideband signal $\hat{s}_{wb}$ by summing the highband signal and

6   the narrowband signal interpolated to the wideband sampling rate.

1   36.   A method of producing a wideband signal from a narrowband signal, the method

2   comprising:

3   (1)   computing M_{nb} area coefficients from the narrowband signal;

4   (2)   computing M_{nb} log-area coefficients from the M_{nb} area coefficients;

5   (3)   interpolating the M_{nb} log-area coefficients into M_{wb} log-area

6   coefficients;

7   (4)   converting the M_{wb} log-area coefficients into M_{wb} area coefficients;

8   and

9   (5)   synthesizing a wideband signal y_{wb} using the M_{wb} area coefficients and

10   an excitation signal.

1   37.   The method of producing a wideband signal from a narrowband signal of claim

2   36, the method further comprising:

3   (6)   highpass filtering the wideband signal y_{wb} to produce a highband signal;

4   and

5   (7)   combining the highband signal with the narrowband signal interpolated

6   to the wideband sampling rate to generate a wideband signal $\hat{s}_{wb}$.

1   38.   The method of claim 36, wherein computing M_{nb} area coefficients further

2   comprises computing M_{nb} area coefficients using the following equation:

3
$$A_i = \frac{1 + r_i}{1 - r_i} A_{i+1}; \quad i = M_{nb}, M_{nb} - 1, ..., 1,$$

4   where A_1 corresponds to a cross-section at the lips, $A_{M_{nb}+1}$ corresponds to a

5   cross-section at the glottis opening and r_i are reflection coefficients.

1   39.   The method of claim 36, wherein interpolating the M_{nb} log-area coefficients

2   into M_{wb} log-area coefficients further comprises interpolating using a linear first order

3   polynomial interpolation scheme.

1   40.   The method of claim 36, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating using a cubic spline interpolation scheme.

1   41.   The method of claim 36, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating using a fractal interpolation scheme.

1   42.   The method of claim 36, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating by a factor of 2, with a ¼ sample shift.

1   43.   The method of claim 36, wherein interpolating the M_{nb} log-area coefficients

2   further comprises interpolating by a factor of 4 followed by a single sample shift and

3   decimating by a factor of 2.

1   44   A method of generating a wideband signal from a narrowband signal, the method

2   comprising:

3   (1)   producing a wideband excitation signal from the narrowband signal;

4   (2)   computing partial correlation coefficients r_i (parcors) from the

5   narrowband signal;

6   (3)   computing M_{nb} area coefficients according to the following equation:

7
$$A_i = \frac{1+r_i}{1-r_i} A_{i+1}; \quad i = M_{nb}, M_{nb} - 1, \ldots, 1,$$

8   where A_1 corresponds to the cross-section at lips and $A_{M_{nb}+1}$

9   corresponds to the cross-section at a glottis opening;

10   (4)   computing M_{nb} log-area coefficients by applying a log operator to the

11   M_{nb} area coefficients;

12   (5)   extracting M_{wb} log-area coefficients from the M_{nb} log-area coefficients

13   using shifted-interpolation;

14   (6)   converting the M_{wb} log-area coefficients into M_{wb} area coefficients;

15   (7)   computing wideband parcors r_i^{wb} from the M_{wb} area coefficients

16   according to the following:

17
$$r_i^{wb} = \frac{A_i^{wb} - A_{i+1}^{wb}}{A_i^{wb} + A_{i+1}^{wb}}, \quad i = 1, 2, ..., M_{wb};$$

18   (8)   computing wideband linear predictive coefficients (LPCs) a_i^{wb} from the

19   wideband parcors r_i^{wb}; and

20   (9)   synthesizing a wideband signal y_{wb} from the wideband LPCs a_i^{wb} and

21   the wideband excitation signal.

1   45.   The method of generating an output wideband signal from a narrowband signal

2   of claim 44, the method further comprising:

3   (10)   highpass filtering the wideband signal y_{wb} to generate a highband signal

4   S_{hb}; and

5   (11)   generating a wideband signal $\hat{s}_{wb}$ by summing the highband signal S_{hb}

6   and the narrowband signal interpolated to the wideband sampling rate.

1   46.   The method of generating a wideband signal from a narrowband signal of claim

2   44, wherein producing a wideband excitation signal from the narrowband signal further

3   comprises:

4   performing linear prediction on the narrowband signal to find a_i^{wb} LP

5   coefficients;

6   interpolating the narrowband signal to produce an upsampled interpolated

7   narrowband signal;

8   producing a narrowband residual signal $\tilde{r}_{nb}$ by inverse filtering the upsampled

9   interpolated narrowband signal using a transfer function associated with the a_i^{wb} LP

10   coefficients; and

11   generating a wideband excitation signal from the narrowband residual signal $\tilde{r}_{nb}$.

1   47.   A method of producing a wideband signal from a narrowband signal, the method

2   comprising:

3   computing M_{nb} area coefficients from the narrowband signal;

4   interpolating the M_{nb} area coefficients into M_{wb} area coefficients; and

5   generating the wideband signal using the M_{wb} area coefficients.

1   48.   The method of generating a wideband signal from a narrowband signal of claim

2   47, wherein interpolating the M_{nb} area coefficients further comprises interpolating by a

3   factor of 4 followed by a single sampling interval shift and decimating by a factor of 2.

1   49.   A method of producing a wideband signal from a narrowband signal, the method

2   comprising:

3   computing M_{nb} log-area coefficients by applying a log operator to M_{nb} area

4   coefficients generated from the narrowband signal;

5   extracting M_{wb} log-area coefficients from the M_{nb} log-area coefficients using

6   interpolation; and

7   generating a wideband signal using M_{wb} area coefficients generated from the

8   M_{wb} log-area coefficients.

1   50.   The method of generating a wideband signal from a narrowband signal of claim

2   49, wherein extracting the M_{nb} log-area coefficients using interpolation further

3   comprises interpolating by a factor of 4 followed by a single sampling interval shift and

4   decimating by a factor of 2.